

# Office of Electric Transmission and Distribution



## Superconductivity Partnerships with Industry

Plugging America Into the Future of Power

### Project Fact Sheet

# Transformer

#### WHAT ARE ITS PRIMARY APPLICATIONS?

Compact, quiet, lightweight, and super-efficient HTS transformers (HTST) will primarily be used at substations within the utility grid. Environmentally friendly and oil-free, they will be particularly useful where transformers previously could not be sited, such as in high-density urban areas or inside buildings.

#### WHAT ARE THE BENEFITS TO UTILITIES?

Utilities will derive many benefits from HTS transformers. HTS transformers are expected to be much more efficient than their conventional counterparts. Since electricity typically passes through five to ten transformers on its way from the generator to the end user, substantial savings can be realized. HTS transformers do not require cooling oil like conventional transformers, which eliminates fire and environmental hazards, and they are much lighter and easier to transport. HTS transformers, therefore, can safely operate almost anywhere. Additionally, with a smaller footprint, HTS transformers can deliver more power per unit volume in existing substations.

From a grid engineering perspective, Waukesha estimates that the HTS transformer will be able to withstand a 2X capacity overload without insulation damage or loss of life. It will have a lower impedance and better voltage regulation capabilities than regular transformers. HTS transformers have the potential to have fault current limiting capabilities as well (see Matrix Fault Current Limiter fact sheet), which could save utilities the cost of associated switchgear, breakers, and damage to circuits in the event of a ground fault. Finally, HTS transformers offer the potential for improving system security. They can interface directly with underground superconducting cables, and with smaller radiators and no oil to spill or ignite, they present a less explosive target during an attack on a system.



The 5/10 MVA Waukesha HTS Transformer

#### WHAT IS THE MARKET POTENTIAL?

Growth in urban power density drives the need for medium power transformers to become smaller, lighter, and free of fire hazard. HTS transformers have all of these attributes. The existing U.S. transformer market for 10 – 100 MVA devices is \$260 million, and there is an additional market of \$120 million for transformers rated greater than 100 MVA. The world market is at least 3 – 4 times larger than these figures and growing twice as fast.

#### WHAT ARE THE PROJECT

#### ACCOMPLISHMENTS TO DATE?

A 1 MVA HTS demonstration transformer was tested in an earlier Waukesha/DOE partnership in 1997. Phase II led to the testing of a 5/10 MVA HTS transformer in late 2003. During testing, some problems were discovered. Partial discharge was observed in the coils of the device, and the team

#### WHAT IS THE STATUS OF THE PROJECT?

The 5/10 MVA HTS transformer has been built and tested. Some issues were discovered during testing that are being repaired. The transformer has been moved into a substation at the Waukesha plant and is being prepared for final grid tests.

## Goal:

Build and operate a 5/10 MVA 26.4 kV alpha prototype high-temperature superconducting (HTS) power transformer on the Wisconsin Electric Power utility grid.

## Team:

Waukesha Electric (team leader)  
SuperPower (wire manufacturer)  
Oak Ridge National Laboratory (supporting research)  
Energy East (utility end user)

## Period of Performance:

1998 – 2005

## Cumulative Project Funding:

Private \$3.825 million (50.0%)  
DOE \$3.825 million (50.0%)  
Total \$7.65 million

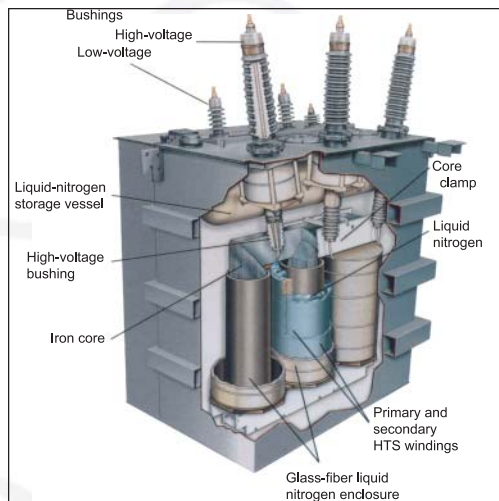
## What is it?

Transformers convert generation-level voltage to transmission-level voltage, and transmission-level voltage to distribution-level voltage. Smaller transformers then convert the distribution-level voltage to consumer level voltages. Changing the voltage of electricity in such a manner reduces the amount of energy lost in the delivery of power over long distances.

## Information

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*Cut-away view of HTS transformer*

discovered some small leaks in the cryogenic system. In addition, there were some issues with shorts at high voltage. Although high voltage issues prevented the team from testing the transformer at its rated voltage, it was successfully tested at twice its rated current. Activities to resolve the problems were undertaken, and the transformer was installed in the substation at Waukesha's plant. Further testing is ongoing.

## How Does it Work?

A transformer is composed of two conductor coils, or "windings," wound around a magnetic core. Via electromagnetic induction, current flows into the primary coil and

out of the secondary coil. Ideally, the input power equals the output power, resulting in zero-loss voltage transformation. However, the coils in conventional transformers are made of copper wire. Resistance in the wire causes a one to two percent loss of energy. HTS transformer coils, made of HTS wire, incur substantially less resistance loss, bringing the efficiency rate of the transformer closer to its potential 100 percent. Additionally, HTS transformers can be designed for greater current densities resulting in smaller windings, which also increases device efficiency per unit volume. Conventional transformers are extremely heavy because of the magnetic core, copper winding, and insulating/cooling oil. Transformers using HTS conductors will be lighter and will require no oil.

The transformer being built in this project is designed to transform electricity from 26.4 kV to 4.2 kV. It is the first HTS transformer designed for use at typical utility distribution



*The final test site for the 5/10 MVA transformer.*

voltage. However, meeting the challenge of containing high voltage and low temperatures in the same device requires extremely precise engineering and construction, and the knowledge gained during this project will be invaluable to future high voltage HTS applications.

## ALIGNMENT WITH ADMINISTRATION PRIORITIES:

**National Energy Policy:** "...expand the Department's research and development on transmission reliability and superconductivity"

**National Transmission Grid Study:** "... accelerate development and demonstration of its technologies, including high-temperature superconductivity..."

**Secretary of Energy:** "... focuses R&D dollars on long-term, potentially high-payoff activities that require Federal involvement to be both successful and achieve public benefit."

**Energy Information Administration:** "of [advanced power delivery] technologies, superconductivity holds the most promise for yielding significant efficiency gains."